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## THE “AMSTERDAM CASTLE”: A CASE STUDY OF WIGGLE MATCHING AND THE PROPER CALIBRATION CURVE

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**ABSTRACT.** We have performed a high-precision  $^{14}\text{C}$  wiggle-matching study on two oak beams from the “Castle of Amsterdam”. These beams are also dated by dendrochronology. Our two dating methods can only be made consistent using the recommended calibration curve (1986) instead of the revised one (1993).

### INTRODUCTION

In the spring of 1994, archaeologists discovered a medieval brick foundation in the center of Amsterdam. Termed “The Castle of the Lords of Amstel”, it was a find of possible great historical importance, especially if it could be dated to AD 1200. A castle at the river Amstel has been described in historical documents but the castle itself has never been found. Large oak beams were found protruding from the brickwork. They were first dated by dendrochronology. The results implied that the foundation was several decades younger than expected. However, a few  $^{14}\text{C}$  dates centered around 1200, using the latest published calibration curve (Stuiver and Pearson 1993). Thus a seeming discrepancy was created between two independent dating methods (Jansma and Kars, 1995). We decided to perform a high-resolution  $^{14}\text{C}$  wiggle-matching study on two of the oak beams that were also dated by dendrochronology, beams “sample 6” and “sample 9”. Our resolution of the discrepancy (van der Plicht 1995) was only possible using the 1986 bidecadal calibration curve (Stuiver and Pearson 1986), instead of the 1993 one (Stuiver and Pearson 1993). We here report on this case study.

### Dendrochronology

The wood samples were compared to available master chronologies, including the Netherlands Historical Chronology 1 (the southern Netherlands/Belgium/Germany; AD 427–1752; Jansma 1995); the Central German Chronology (690 BC–AD 1975; Hollstein 1980); the Weserbergland Chronology (Germany; AD 1004–1970; Delorme 1973); the Eastern Belgium Chronology (AD 672–1986; Hoffsummer 1989); and the Lower Saxony Growth Region 1 Chronology (Germany; AD 915–1991; Leuschner, unpublished data). The chronologies used and the statistics that accompany the dendrochronological dates of samples 6 and 9 are shown in Table 1.

The tree rings in sample 6 date from 1157 to 1272. The number of missing sapwood rings was estimated as  $4 \pm 2$ , so that tree number 6 was felled between 1274 and 1278. The tree rings in sample 9 date from 1103 to 1215. In addition, 30 sapwood rings (including the last formed ring) were counted. Tree number 9 therefore was felled in 1245.

### Radiocarbon

The results of the radiocarbon measurements for trees number 6 and 9 are shown in Table 2. We dated the sapwood samples (23 and 24 rings, respectively), and groups of 10 annual rings as indicated in the table. The rings are counted from the outside; here they are used only in a relative way. The samples were analyzed for  $^{14}\text{C}$  with the highest possible precision in the large (25 liter) Groningen counter.

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TABLE 1. The Match Between Samples 6 and 9 and Some Master Chronologies

Sample	n*	Date of last measured ring	Missing sapwood	Felling date	Master chronology	PV†		t-value‡		α§	
						Width#	Index**	Width	Index	Width	Index
6	116	1272	4 ± 2	1276 ± 2	Netherlands historical 1	64.8	64.8	7.11	7.03	0.005	0.005
					Central Germany	68.3	68.3	7.78	7.67	0.0002	0.0002
					Weserbergland	66.5	66.5	5.06	5.00	0.0005	0.0005
					Eastern Belgium	61.3	61.3	5.32	5.26	0.02	0.002
9	113	1215	30	1245	Netherlands historical 1	62.1	62.9	4.74	4.88	0.02	0.01
					Central Germany	62.1	62.9	3.89	4.07	0.02	0.01
					Weserbergland	69.6	67.9	4.95	4.70	0.0001	0.0002
					Niedersachsen sub 1	62.9	64.7	4.71	4.55	0.01	0.005

\*n = number of rings; †PV = percentage parallel variation; ‡t = student's t-value; §α = level of significance; # = series of total ring width; \*\* = series of standardized and detrended ring widths

TABLE 2. Tree-Ring <sup>14</sup>C Measurements for Samples 6 and 9

Sample no.	Lab code	<sup>14</sup> C age		Tree ring
		GrN-	(BP)	
6	21167	757 ± 15		0–23 (sapwood)
	21175	817 ± 10		33–43
	21177	839 ± 12		53–63
	21178	839 ± 13		63–73
	21180	870 ± 12		83–93
	21182	862 ± 9		103–113
9	21154	807 ± 11		0–24 (sapwood)
	21156	844 ± 17		28–38
	21158	848 ± 10		48–58
	21160	853 ± 17		68–78
	21162	906 ± 18		88–98
	21164	930 ± 17		108–118
	21166	952 ± 10		128–138

The set of  $^{14}\text{C}$  dates for each tree can be "wiggle-matched" to the calibration curve by minimizing the quantity

$$\sum_i [\text{BP}_i(\text{curve}) - \text{BP}_i(\text{date})]^2 \quad (1)$$

(Pearson 1986).

The solution of the wiggle-match procedure to the recommended bidecadal calibration curve (Stuiver and Pearson, 1986) is shown in Figure 1 (sample 6) and Figure 2 (sample 9). The figures show the calibration curve (solid line), the  $1\sigma$  error envelope of the curve (dotted line), the individual calibration data points and—drawn as rectangles—the set of data matched to the curve. The sides of the rectangles represent the error bars: vertically, the errors ( $1\sigma$ ) for the  $^{14}\text{C}$  dates and horizontally, the ring width of the samples. For sapwood, this is 23 rings for tree number 6 and 24 for number 9; in all other cases, 10 annual rings were taken. Note that also the calibration data points are bidecadal and are thus an average for 20 annual rings. The cutting date of the tree, deduced from this procedure, is 1278 cal AD for sample 6 and 1250 cal AD for sample 9.

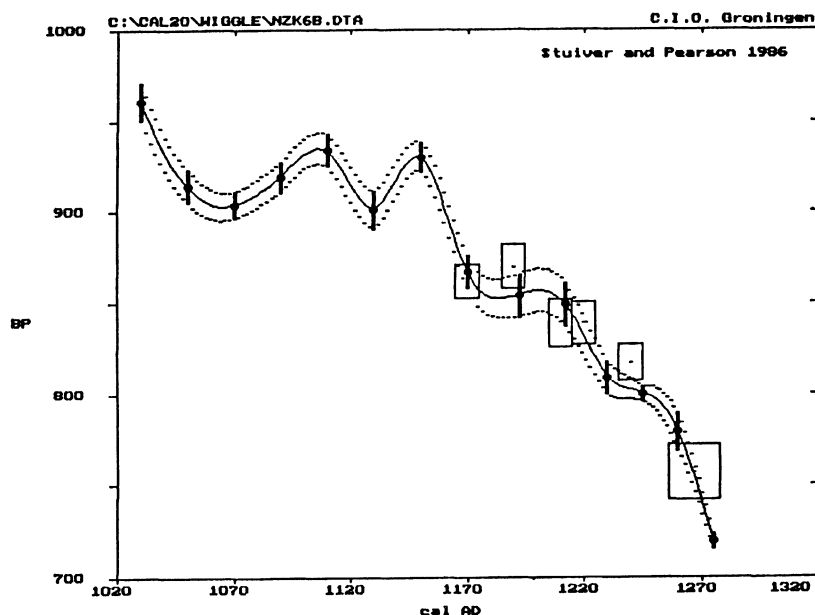


Fig. 1. Wiggle-matched result for wood sample 6

### The Calibration Curve

The results of the case study reported here, obtained by two independent dating methods, dendrochronology and radiocarbon, are in excellent agreement.

For the radiocarbon part of the exercise, this agreement could only be obtained by high-resolution wiggle matching to the 1986 calibration curve (Stuiver and Pearson 1986), which formally is still recommended (Mook 1986). This curve has been revised recently by applying a correction of 18 radiocarbon years (Stuiver and Pearson 1993). Using this corrected calibration curve, agreement between the dendro- and  $^{14}\text{C}$  dates in the case study reported here is not possible: the cutting dates of the trees considered are then 15–20 (calendar) years too young. This observation therefore sup-

ports the contention of McCormac *et al.* (1995) that the revision of the calibration curve in hindsight is not justified.

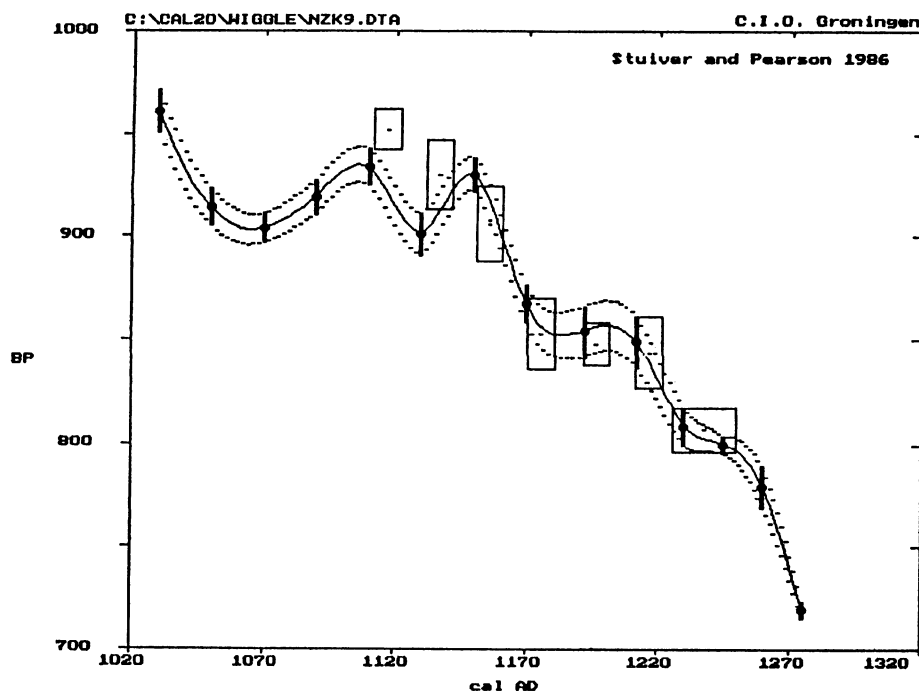


Fig. 2. Wiggle-matched result for wood sample 9

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